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ABSTRACT

A three-year project involving 4,000 students from 15 schools for deaf students supported the development and evaluation of computer-assisted instruction (CAI) for the hearing-impaired. Activities ranged from evaluations of specific curriculums to theoretical studies of language use by the deaf. The project demonstrated that CAI can benefit deaf students, that it can support relevant research in deaf education, and that it is economically feasible. In addition, the outcomes of the project made it clear that CAI can be used for other purposes. These include: 1) the development of symbolic representations of the learner so that specific instructional treatments can be prescribed to maximize educational outcomes; 2) the creation of teaching strategies which respond to wrong answers, allow multiple responses, and permit student control; 3) the identification of the specific cognitive skills of deaf students, and 4) the specification of the economic and technological feasibility of CAI. (LB)

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Computer-assisted Instruction for the Deaf

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This paper concerns the design and evaluation of computer-assisted instruction (CAI) for hearing-impaired, or 'deaf', students undertaken by the Institute for Mathematical Studies in the Social Sciences (IMSSS) at Stanford University. The project was funded for three years, from July 1, 1970 to June 30, 1973. During this period more than 4,000 students from 15 schools for the deaf in California, the District of Columbia, Florida, Oklahoma,and Texas participated in the project. General descriptions of the project were given by Fletcher, Jamison, Searle, and Smith (1973), Fletcher and Suppes (1973), and Suppes (1971).

The aims of the project were to demonstrate that CAI could benefit deaf students, that it could support relevant research in deaf education, and that a favorable argument could be made for the economics of CAI. Behind these aims was the general intent of initiating large-scale use of CAI by schools for the deaf. Fletcher and Suppes (1973) concluded that these aims were all met. However, they emphasized that work completed under the project properly represents beginnings. The intent of this paper is to identify and discuss some of these beginnings under the following four topics: symbolic representation of the learner, teaching strategies, cognitive skills of deaf students, and economics and technology of CAI. Clearly, these topics were not the unique concern of this project and/or of IMSSS; nor were they the only topics of concern in CAI for the deaf. However, they identify some

promising beginnings that were made by the project.

The Stanford CAI System

The central processor for the IMSSS CAI system is a Digital Equipment Corporation PDP-10. In addition to 256K of core memory, short-term storage of programs and student information is provided by movable-head disks. Long-term storage of student response data is provided by magnetic tape. Communication with remote student terminals in schools that participated in the project was provided by private telephone lines. High-speed data transmission and time-division multiplexing were used to communicate with clusters of 16 or more student terminals. In 1972-73 more than 180 terminals were connected to the IMSSS system. About 90 of these terminals could be used simultaneously with no appreciable detriment in the system's speed of response. Any curriculum or other program could be run at any time on any student terminal.

The student terminals were 'KSR Model 33' teletypewriters. These teletypewriters communicated with the central computer system at a rate of about 10 characters per second (110 baud). They provided no photographic or graphic capability but they permitted development of CAI that has produced significant gains in pedagogical achievement for hearing students (e.g., Fletcher and Atkinson, 1973; Jamison, Suppes,and Wells, 1973; Suppes and Morningstar, 1970), and similar gains were anticipated for the population of deaf students.

All CAI curriculums developed by IMSSS were available to students in the participating schools for the deaf. Some of these curriculums, such as reading (grades K-3), French, and Russian, were inappropriate because they

required audio. However, most IMSSS curriculums, even though not specifically designed for hearing-impaired students, were used successfully by the participating schools. The following CAI curriculums were used: elementary-school mathematics, arithmetic word problem solving, language arts for the deaf, algebra, basic English, computer programming in AID, computer programming in BASIC, and mathematical logic. Additionally, several games such as hangman, poster, pico-Fermi-bagels, spelling, and Spanish were used by the students.

Symbolic Representation of the Learner

One line of recent research on instruction has been to establish symbolic representations of the learner so that specific instructional treatments can be prescribed to maximize specific educational outcomes. In practice, these representations have been mathematical models of learning (Atkinson, 1973; Atkinson and Paulson, 1972; Laubsch, 1970; Lorton, 1973). Any model is by design an incomplete and oversimplified representation, but its implications and limitations can be precisely derived and are subject to empirical verification or denial. Those who work with models generally assume that it is better to be precisely wrong than vaguely right. The major task in developing models for CAI is to insure that they account for significant (as opposed to trivial) educational outcomes. The salient feature of these symbolic representations for CAI is that they can be 'understood' by computers... they imply algorithms.

Suppes, Fletcher, and Zanotti (1973a) reported an experiment designed to investigate the utility of predictive-control integrated within CAI. A performance goal, defined in terms of grade placement (GP), for progress over a predetermined time period was set for each of 197 subjects chosen from the

entire population of students who were enrolled in three participating residential schools for the deaf in California, Texas,and Florida. Each subject was then assigned to one, two,or three daily CAI sessions for each of six two-week periods depending on his progress toward his goal. Each subject was represented by a model of the following form:

$$E(GP_i) = a_i + b_i S_i^c \quad , \quad 0 < c \leq 1$$

Where GP_i is the grade placement of student i,

S_i is the number of sessions taken by student i,

a_i and b_i are unique parameters of the model calculated for student i.

Two forms of these models were used:

$$E(GP_i) = a_i + b_i S_i^{1/3} \qquad (1)$$

$$E(GP_i) = a_i + b_i \ln(S_i) \qquad (2)$$

At the end of the experiment, the standard errors of estimate for 90% of the subjects ranged from .013 to .114 years in GP for (1) and from .016 to .131 years in GP for (2).

Although the intensity of treatment - - amount of CAI time - - given a student may be highly and, under CAI, precisely individualized, the goal set for him can be unreasonable if it, too, is not tailored to a model of his progress. Suppes, et al. emphasized that their approach permits individualization of instruction both in the amount of instruction required and in the goal set for each student.

This experiment was successful in showing that predictive-control could be usefully built into CAI, and it was replicated using a population of

American Indian students (Suppes, Fletcher,and Zanotti, 1973b). However, the extent to which objectives can be met by such a technique cannot be settled by one or two experiments with a single curriculum,and the technique itself is only a beginning. For deaf subjects, the model might be made more precise by the addition of student background information such as chronological age, average hearing loss in the better ear, early experience with manual communication, age of hearing loss, number of years in special schools and/or classes for the deaf, sex, and standard test scores. This information could easily be included in the earlier model. It would increase our understanding of how different subpopulations of deaf students profit from various CAI curriculums, and the precision with which individual student's progress is predicted could be improved.

Teaching Strategies

Four issues that commonly arise in the design of CAI are the following: the utility of providing 'tailored' wrong answer messages for specific, anticipated wrong answers; the utility of allowing consecutive second and third guesses after a student responds incorrectly; the utility of requiring a student to respond correctly immediately after he has made an incorrect response and has been told the correct answer; and the utility of providing student-control features.

Fletcher and Beard (1973) reported three experiments relevant to the first three issues. The experiments were integrated within a tutorial language arts CAI curriculum that was especially designed for deaf students. One hundred thirty eight language arts students chosen at random from three residential and five day schools for the deaf were randomly assigned to one

of the two groups in each of the three experiments. These assignments were made automatically by computer program when each subject began the language arts curriculum.

In the first experiment, one group received correction messages that were tailored for specific, anticipated wrong answers. The second group did not receive these messages; they were told only that their incorrect answer was wrong. Fletcher and Beard reported no practical or significant difference in achievement between the two groups of subjects. Considerable time and expense are ordinarily allocated to constructing tailored correction messages for tutorial CAI. This was the case for the language arts curriculum, and an item-by-item analysis of the wrong answers given indicated that the correction messages were appropriate. It may be that constructing useful correction messages is far more complex than is currently imagined or that correction messages that seem reasonable to educational researchers (both hearing and deaf) are inappropriate for deaf students. In any case, further investigation of this issue is warranted for practical, if not theoretical, reasons.

In the second experiment, one group received three consecutive trials per exercise; the second group was allowed only one trial per exercise. Posttreatment measures revealed significantly superior achievement for the three-trial group over the one-trial group. It may be that a student who is told that an answer he gave was wrong receives relatively little information; it is more informative for him to receive positive corroboration of an hypothesis that he has generated.

Both treatment groups in the third experiment received an explicit correct answer after making an incorrect response. However, members of

one group, the explicit rehersal group, were required to echo (type) the correct answer after it was given, and members of the second group, the implicit rehersal group, were not required to do so. Posttreatment achievement was significantly superior for the explicit rehersal group. Despite random assignment of subjects to the two treatment groups, pretreatment achievement was also significantly superior for the explicit rehersal group. The results of the third experiment are therefore inconclusive.

There was to be a fourth experiment on the utility of student-control features such as hints, skips, and student initiated branching. This experiment was designed and implemented, but use of the student-control features was practically non-existent and did not warrant collection and analysis of student data. The error in designing this experiment may have been that use of the student-control features had to be initiated by the students, not by the curriculum. If use of the student-control features had been required by the curriculum, the features would, at least, have been used. Beard, Lorton, Searle, and Atkinson (1973) reported an experiment in which college-age, hearing students were required to choose what lesson to take next after finishing a lesson. They found that because their lessons were numerically identified, their subjects simply chose the next lesson in numerical order despite the great amount of information that had been made available to them concerning course objectives and lesson contents.

The practical and theoretical implications of these experiments should be obvious, but the results from these experiments are in no sense final. The issue of student control is a case in point. For some students, some type of student-control in some instances may be invaluable; the problem is to find for whom, what, and when. The value of blanket affirmations or denials of

student-control and other teaching strategies may be vitiated by the complexity of the issues.

Cognitive Skills of Deaf Subjects

Early reviews suggested that the educational difficulties of the deaf were due to a general cognitive deficit. More recent reviews of research challenge these claims and suggest that the distribution of intelligence is similar for deaf and hearing populations (Bonvillian, Charrow, & Nelson, 1973; Furth, 1964; Vernon, 1968). In the absence of a general cognitive deficit explanation for the educational difficulties of the deaf, specific cognitive skills of deaf students are of primary interest. Several investigations of these skills were undertaken for the CAI project, two of which are discussed here.

Suppes and Flannery (in preparation, but also discussed by Suppes, 1972) used register machine models to compare the performances of deaf and hearing students on elementary-school mathematics CAI. These models permitted comparisons of the specific algorithmic processes that the students used to solve problems. Suppes and Flannery reported two major conclusions. The first conclusion was that objective features of the curriculum, for example whether a vertical addition problem has a carry or not, dominated the difficulty of exercises in much the same way for both deaf and hearing students. The second conclusion was that the performance of the deaf children was almost always slightly better than that of the hearing children. The data suggested, therefore, that it should be possible to obtain results in arithmetic for deaf students that are as good as those for hearing children.

Fletcher and Beard (1973) attempted to discover useful dimensions of difficulty that affected performance on language arts items taken by deaf

students and reported several results that are not widely noted in the literature on deafness. Three of these results were that deaf students had far less difficulty following directions than generally anticipated, that possessive pronouns were generally easy for the students but those that differed in number and/or gender from the norms they modified were very difficult for the students,and that copulas joining subjects with predicate complements were easy for the students except for those that differed in number from the subjects they complemented were very difficult.

Aside from the specific findings it is important to note that both the Suppes and Flannery study and the Fletcher and Beard item analysis would have been far more difficult to complete outside of the context of CAI. More investigations are needed on the cognitive skills of deaf students, and more use should be made of the response protocols of students taking CAI. Again these studies represent beginnings which, hopefully, will be continued by other researchers.

Economics and Technology of CAI

The study of the economics and technology of the CAI network maintained for schools that participated in the project was discussed by Ball and Jamison (1973) who emphasized that the decision of whether to provide CAI and how much CAI to provide depends not only on cost per session but on two other crucial factors. First is the performance of CAI in raising student achievement. Second is the issue of priorities -- what must be given up in order to have CAI. On the basis of schools and classes for the deaf, Ball and Jamison concluded that substantial amounts of CAI and concomitant improvements in student achievement are feasible with only minor increases in student-to-staff ratios.

Four implementation alternatives were also discussed for expanding the Stanford-based CAI network of participating schools and classes for the deaf, but these alternatives are not detailed here. The point is that the economics and technology of providing CAI were studied as an integral part of the project and not as an afterthought. Those who worked on the project, as well as representatives of the granting agency, felt that investigations of educational technology are too often concerned solely with the effects of the technology and not with the administrative aspects of implementing it. On the other hand, those who have investigated cost and effectiveness of education have too often limited their studies to traditional forms of educational inputs (e.g., Coleman, Campbell, Hobson, MacPartland, Mood,Weinfeld, and York, 1966). As Jamison, Fletcher, Suppes, and Atkinson (1971) pointed out, the pessimistic conclusions of these studies may be obviated by the economics and effectiveness of non-traditional school inputs such as CAI. Clearly, more investigations are needed, and clearly no study of an educational innovation should be viewed as complete without some discussion of the administrative aspects of implementing it.

A Concluding Note

One promising beginning that is difficult to classify is that the work of maintaining the project was shared with the deaf community. Deaf adults and older students served as proctors, deaf students were trained to maintain and repair the teletypewriters and data communication equipment used by the project, and, because the CAI was offered on a general purpose timesharing system, several deaf students learned programming and contributed useful programs to their schools and to the project. All this activity was heartening, but few things are perfect. There were no formal mechanisms in the project

for channeling the new interests and skills of these students into employment and/or education opportunities.

Informally, most of these students were given guidance by concerned members of the project staff, but a great deal more could have been accomplished if this process had been formally integrated into the project. Hopefully, in future investigations of this sort, particularly those that involve the educationally handicapped, aspects of rehabilitation will be included as more than incidentals.

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Footnote

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